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Ranking Thinning Potential of Lodgepole Pine Stands

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INTRODUCTION

Determining thinning priorities among stands is a persistent problem in the management of lodgepole pine forests (Weyermann 1965; Cole 1975). Both economic and biological influences must be considered, but thinning studies have not yet been conducted in a wide enough array of age, site, and density conditions to provide adequate thinning response equations. This limits computerized growth and yield simulations as a means for prioritizing lodgepole pine thinning opportunities, until better data are available.

The Intermountain Research Station has taken a dual approach to the problem. A long-term program of empirical thinning studies will eventually provide data for developing comprehensive managed-stand growth functions. This will allow reliable computer simulations of stand growth and yield for a complete range of stand conditions and management alternatives. When this capability is reached, projected yields for the same hypothetical level of thinning can be compared for a number of stands to determine their priority for thinning. In the interim, the Intermountain Station has cooperated with the Intermountain Region, USDA Forest Service, in a study to develop a method for using the response of edge trees of existing clearings, as an indicator of the relative thinning response potential of stands. Stem analysis was used to obtain tree and stand values prior to and at the time of clearing for analysis of their relationship to subsequent response of edge trees to the clearing. The method indicated that linear regression relationships were effective in predicting the response to clearing of dominant and codominant trees on stand edges (Cole 1986).

The purpose of this paper is to present a choice of edge-response models for field application and to provide instructions for calculating a Thinning Response Index for overstocked lodgepole pine. Included are data requirements, sampling procedures, examples of model solutions and stand rankings, and suggestions for management applications.

EDGE RESPONSE EQUATIONS

Three models considered useful in field applications are presented in table 1, where the variables and their abbreviations are identified. Model 1 was described in a previous paper (Cole 1986). As discussed there, model 1 effectively predicts edge response to clearing and provides a basis for ranking different stands according to their predicted response. For practical management applications, table 1 also provides two other models—models 2 and 3—to better capitalize on existing data bases.

Table 1—Regression models of lodgepole pine edge response to thinning

Model No.	Regression equation	R^2
1	$y = 0.0051 + 0.0579\text{CSI10B} + 0.0057\text{SI}_{100} + 0.0381\text{QMSD}$	0.59
2	$y = -0.1746 + 0.0250\text{CSI10B} + 0.0067\text{SI}_{100} + 0.0699D$	.63
3	$y = -0.1221 + 0.1084D + 0.0054\text{SI}_{100} - 0.0016A$	.63

where: y = $\log_{10}$ CSI10B (Response of dominant and codominant edge trees, in square inches in the 10 years before clearing)
CSI10B = cross-sectional increment in square inches in the 10 years before clearing
SI_{100} = site index at 100 years, as corrected for stand density (Alexander and others 1967)
QMSD = quadratic mean stand diameter in inches
D = mean d.b.h. of dominant and codominant trees in inches
A = mean age of dominant and codominant trees in years.

Limits of application for the models of table 1 are:

CSI10B (previous 10-year cross-sectional increment) – 0 to 6.0 in^2.

SI_{100} (site index at 100 years) – 35 to 85 ft.

QMSD (quadratic mean stand diameter) – 1.0 to 6.0 inches.

D (mean diameter of dominant and codominant trees) – 2.0 to 9.0 inches.

A (mean age of dominant and codominant trees) – 30 to 100 years.

The great majority of overstocked lodgepole pine stands—particularly those below merchantable size—will have values of the independent variables that fall within the above ranges. Stands having higher values of CSI10B, but values within the ranges of the other variables, are probably not overstocked and thus are not relevant for ranking against overstocked stands.

INDEXING EDGE RESPONSE ESTIMATES

Edge response to clearing is not equivalent to response of dominant and codominant trees to normal thinning; therefore, predicted responses from the models of table 1 should not be viewed as estimates of actual growth response to thinning. To dissuade this inclination, predicted values from the regression models are converted to a Thinning Response Index (TRI) with the relationship:

$$\text{TRI} = 10^{y}/12.0$$

where y is the common logarithm of CSI10A, the edge response predicted from the chosen equation of table 1, and the constant 12.0 is an arbitrary value near the upper limit of edge response observed.

In comparing stands, the higher the TRI value a stand has, the higher its rank for expected response to thinning. Thinning Response Index (TRI) thus is considered a relative biological index for ranking potential stand response to thinning.

HOW TO USE THE METHODS

Comparing and Choosing Models

Data required for the models can be obtained by sampling stands, or data may already be available or easily computed from recent stand records. Users can pick the most efficient model for their situation from table 1. Whichever model is chosen, it should be used exclusively for each stand under consideration. Likewise, Thinning Response Indexes from one edge-response model should not be compared with those from another model when ranking stands. Index values are unitless; thus they mask the fact that different stand parameters reflecting thinning potential are involved in the different models.

To illustrate the process of comparing and choosing models and to test the models' performance in prioritizing stands for thinning, independent data were obtained from four overstocked stands on the Deerlodge National Forest in Montana. Data values, regression model solutions, calculated values of the Thinning Response Indexes for each model and stand, and the relative thinning priority of the stands as indicated by the models, are summarized in table 2.

Table 2—Values of independent variables, model predictions, thinning response indexes (TRI), and relative biological thinning priorities of four Deerlodge National Forest stands

Stand No.	Independent variables				
	D	CSI10B	*A*	SI_{100}	QMSD
1	4.95	3.00	88	78	3.83
2	4.31	2.82	88	69	3.08
3	3.19	1.67	88	70	2.13
4	6.49	5.04	59	83	4.95

Model predictions (y)[1] and thinning response indexes (TRI)[2]: Model 1		Model 2		Model 3		Relative thinning priority[3]
y	TRI	*y*	TRI	*y*	TRI	
0.77	0.49	0.77	0.49	0.69	0.41	2
.68	.40	.66	.38	.58	.32	3
.58	.32	.56	.30	.46	.24	4
.96	.76	.96	.76	.94	.73	1

[1]y = common logarithm of CSI10A (mean 10-year cross-sectional increment of dominant and codominant trees—see table 1 for specific regression equation representing each model).

[2]Thinning response index (TRI) = $10^y/12.0$.

[3]Relative thinning priority of stands (1 = highest and 4 = lowest values of TRI) was the same for all models.

All three models performed similarly in predicting the relative edge-response of the four stands, each yielding the same order of relative thinning priority among the stands as determined by the magnitude of their Thinning Response Indexes (TRI's). The order or ranking of TRI's of the four stands of table 2 was compared (table 3) with a composite ranking from several factors commonly understood to influence stand vigor and growth (such a ranking of factors is useful for several stands as involved here, but it would not be reliable for distinguishing between a much larger number of stands). This comparison indicates that the models produce results that are consistent with biological expectations for the stands, as shown by the agreement of the composite factor rankings in table 3 with the TRI rankings.

On the basis of the above comparisons, the model that allows the least effort and expense in data collection should be the preferred choice for a specific management application. For example, if basal area and average stand diameter by basal area (QMSD) are already known for stands under consideration, then model 1 would probably be the preferred choice. A sample of mean height of dominant trees and the last 10 years radial growth of dominant and codominant trees is necessary to compute density-corrected SI_{100} and CSI10B.

On the other hand, if QMSD is not already available, but mean age of dominants and codominants (*A*) is available, model 3 is probably the best choice. Mean age of dominants and codominants (*A*) and stand age as determined from the main stand overstory in even-aged lodgepole pine stands are often equivalent.

If mean age of dominants and codominants (*A*) is not already available, the choice between models 2 and 3 is a tossup. In this case the manager would have to evaluate whether collecting and measuring increment cores for CSI10B (model 2) is easier than determining age (*A*) from a stump core for use in model 3.

The following sections suggest procedures for obtaining stand data, and provide formulas and instructions for computing values of the variables required for the model(s).

Table 3—Comparison of relative factor effects and composite factor-response ranking with ranking by thinning response index (TRI)

	Relative factor effect[1]						
Stand No.	Age	SI	Trees/acre	QMSD	Stand density index	Composite rank[2] of factors	TRI rank
1	II	II	II	II	II	2	2
2	II	III	II	III	III	3	3
3	II	III	III	IV	IV	4	4
4	I	I	I	I	I	1	1

[1] I = highest, IV = lowest.
[2] 1 = highest, 4 = lowest.

Obtaining Stand Data

If not already available in stand records, the following steps should be taken to secure data needed for the ranking procedures:

Step 1—Examine candidate stands with stereoscopic aerial photos, if available, to help determine stand size and boundaries.

Step 2—At the site, confirm stand boundaries and establish at least four random sampling points in representative portions of the stand.

Step 3—At each sampling point, select as sample trees the nearest dominant and codominant trees typical of trees that would be left after thinning.

Step 4—From each sample tree obtain measurements and age and growth samples appropriate to the response model selected for use.

From each dominant tree, an increment core should be obtained at stump height (0.5 ft) to determine tree age. If model 3 is to be used, an increment core should also be taken at stump height from the codominant sample tree at each sampling point to allow determination of the variable *A*. If annual rings can be counted in the field, the count can be entered in the field data form and the increment core discarded; otherwise, if rings are too narrow for field counting the increment core should be sealed in a labeled plastic straw for counting under magnification in the office. In either case an assumed 2 years to reach 6-inch height should be added to the ring count to represent total age of the tree.

The dominant tree chosen at each point should also be measured for total height to provide values for determining site index.

Other measurements will be taken at each sampling point, according to the model chosen from table 1. If models 2 or 3 are chosen, d.b.h. outside bark should be measured on the dominant and codominant sample trees to allow computation of the variable *D*. If models 1 or 2 are chosen, CSI10B must be determined. To provide for this, two increment cores, including the last 10 years' radial increment, should be obtained at breast height from opposite sides of dominant and codominant sample trees. Each core should be inserted in a plastic straw and sealed with plastic tape on which is written stand, sampling point, and tree numbers and the crown class and core number of the sample tree. The opaque types of cellulose acetate tape, commonly called "invisible tape," work well for sealing the ends of the straws and can be written on with ballpoint pen or pencil. If increment cores are not to be measured within a few days they should be stored in a freezer to prevent fungal growth from obscuring growth rings.

Before leaving a sampling point, a variable-plot tally of basal area and stand density should be made to provide data for calculating crown competition factor (CCF), site index (SI_{100}, and the quadratic mean stand diameter (QMSD). The diameter of each "count tree," determined with an angle gauge or prism, is measured to the nearest 0.1 inch at breast height and recorded on the field form. The same basal area factor (BAF), of angle gauge or prism, should be used for each

sampling point of a stand. For the range of stand densities being considered, a BAF of 20 ft^2/acre is recommended. A sample form for recording data and computing variables is shown in appendix A.

Calculating Variables

Values of all variables used in the ranking models must be computed from field data if not already available in stand records. Following are instructions for calculating each needed variable:

1. **Mean cross-sectional increment in past 10 years (CSI10B)** should be determined from breast height increment cores of the most recent 10 years of radial increment of dominant and codominant sample trees, excluding the current year (in which growth might not be complete). For each tree the 10-year radial growth (RG10) from the two cores is measured to the nearest 0.01 inch and averaged. Diameters of the tree at the beginning and end of the growth period are required to calculate the cross-sectional increment (bark thickness is assumed to remain constant). Current diameter (d.b.h.) is measured in the field. Diameter 10 years before (D_B) is found by doubling the average radial growth determined from the increment cores and subtracting it from the current diameter (d.b.h.). Cross-sectional increment (CSI) is calculated as the difference between the cross-sectional area in square inches of diameters d.b.h. and D_B. This is shown by the formula:

$$\mathrm{CSI} = \pi \left(\frac{\text{d.b.h.}}{2}\right)^2 - \pi \left(\frac{D_B}{2}\right)^2,$$

where the constant, π, has the value 3.1416. Average cross-sectional increment values for each sample tree at a sampling point are summed and divided by the number of them to obtain the plot mean of cross-sectional increment in the past 10 years (CSI_p), of dominant and codominant trees. The plot means (CSI_p) are summed for all sampling points in the stand and divided by the number of sampling points to obtain the stand mean CSI10B. This value is recorded for use in the regression equation models of table 1.

2. **Mean age (A)** is determined by summing the ages measured from stump cores of the dominant and codominant trees of the stand and dividing by their number. The resultant value is recorded for use with model 3 of table 1.

3. **Mean diameter (D)** is determined by summing the sampling point average d.b.h.'s of the dominant and codominant sample trees (D_p) and dividing by the number of sampling points. The resultant value is recorded for use with models 2 and 3 of table 1.

4. **Quadratic mean stand diameter (QMSD)** is obtained as the average of the quadratic mean stand diameters of the sampling points. For each variable-plot sampling point of the stand, basal area (BA_p) in square feet per acre is calculated by multiplying the BAF by the number of "count" trees. The number of trees per acre represented by each of the n "count" trees is calculated with the formula:

$$\mathrm{TPA}_i = \mathrm{BAF}/0.005454 D_i^2$$

where BAF is the basal area factor in square feet per acre of the angle gauge or prism, D is the d.b.h. of the "count" tree, and $i = 1$ to n. The total number of trees per acre (TPA) represented by the sampling point is then determined by summing the numbers of trees per acre represented by each "count" tree. The sum of the number of trees per acre of the sampling point is used with the point basal area to determine the mean tree basal area (TBA_m) in square feet of trees at the sampling point:

$$TBA_m = \frac{BA_p}{\Sigma TPA_p}$$

Quadratic mean square diameter ($QMSD_p$) is the diameter in inches of the tree of mean basal area. It can be calculated with the following equation which includes the conversion from square feet to square inches:

$$QMSD_p = \sqrt{183.3465\ TBA_m}$$

where $QMSD_p$ is in square inches and TBA_m is in square feet per acre. To obtain the overall mean stand value of QMSD the $QMSD_p$ values of all sampling points are summed and divided by the number of sampling points. The resultant value of QMSD should be recorded for use in model 1 of table 1.

5. **Site index (SI)** is computed as the average of stand density-corrected site indexes determined for each sampling point of the stand. The lodgepole pine site index used in this study was that developed by Alexander and others (1967). These site index curves were corrected for stand density as expressed by crown competition factor (CCF) (Krajicek and others 1961). They are presented as tables 4-8 in appendix B from which sampling point site index values might be obtained (interpolating where necessary), using sampling point values of dominant tree age and height and CCF.

The total height of the dominant (site) tree can be calculated from field clinometer data. This is done according to the formula:

$$H = \frac{d}{100}(TR - BR),$$

where H is total height in feet, d is distance in feet, and TR and BR are clinometer readings of the top and bottom of the tree, respectively.

Crown competition factor (CCF_p) must also be calculated for each sampling point to allow use of Alexander's site index tables. Alexander and others (1967) presented an equation for computing lodgepole pine CCF from stand basal area (BA) and quadratic mean stand diameter (QMSD):

$$CCF_p = 50.58 + 5.25\ (BA_p/QMSD_p)$$

Using basal area and QMSD values for the sampling point, a CCF value for the sampling point can be calculated with this equation and used with the calculated dominant height and measured dominant age values to enter the appropriate site index table and determine the density-corrected site index value of the sampling point. Interpolation

between the height, age, and CCF classes of the tables will usually be necessary. After obtaining and recording the density-corrected site index (SI_p) at each sampling point, a mean density-corrected site index for the stand is obtained by summing the sampling point site indexes and dividing by the number of sampling points. This mean stand value of site index (SI_{100}) is then recorded for use in regression models of table 1.

SOME MANAGEMENT APPLICATIONS

If a manager intends to thin only stands having the highest potential thinning response, he can choose the appropriate model for his particular situation and determine the Thinning Response Indexes (TRI's) to identify the qualifying stands. A field forester might likewise use the same approach to determine whether or not a specific stand qualifies for thinning.

Similarly, where a decision has been made to thin a certain number of acres of stands likely to give the best growth response to thinning, TRI's can be sorted into a descending order of predicted stand response. With acreage data on each stand in the list, the planned amount of thinning can thus be assigned to the stands more likely to give the best response.

Other uses can be made of the procedures given here. For example, stands having the lowest response potential might be of interest. It might be desired to identify these and select a certain number or certain acreage for stand replacement to enhance such objectives as habitat diversity or age-class mosaics. This could be done by computing the TRI's from one of the models presented here for all stands under consideration. By sorting the TRI's into ascending order and referring to the stand acreages involved, the desired acreage of "best" stands for meeting such stand replacement objectives could be identified.

SUMMARY

All three of the alternative models performed similarly in ranking thinning potential of the test stands reported here, but users are reminded against mixing models in comparing the Thinning Response Indexes (TRI's) of a number of stands. If this stipulation is followed, stand rankings based on TRI's, should portray the relative biological potential of the stands for thinning response. Ultimately this can only be confirmed or disproved by ranking a goodly number of stands by these methods, thinning them to a common prescription, and comparing their actual order of thinning responses after 10-15 years with the predicted order. These tests by the Intermountain Research Station are already under way in 20 recently thinned stands in Montana and Utah.

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APPENDIX A—DATA FORM AND COMPUTATIONAL F(DETERMINE POTENTIAL THINNING I

PERSON COLLECTING DATA: ______________________________

DATE: ____________________ **STAND BAF (Ft^2/acre)**

		Past Radial Growth (PRG)				
		Years 1-5		Years 6-10		Stum
	d.b.h.$_i$	Core 1	Core 2	Core 1	Core 2	Age (/
	in	*0.01 in*	*0.01 in*	*0.01 in*	*0.01 in*	*yrs*
Dominant Tree						
Codominant Tree						

VARIABLE PLOT CRUISE (Enter D_i of "Count" Trees, i = 1 to n)

Tree No.:	1	2	3	4	5	6	7
D_i (0.1 inches):							
Trees/acre (TPA):							

COMPUTATIONAL I

Individual Trees	Sam
$\pi = 3.1416$	$TPA_p = \Sigma TPA_i =$ ______
$RG5 = PRG(1\text{-}5) =$ ______________________	$D_p = \Sigma d.b.h._i/2 =$ ______
$RG5P = PRG(6\text{-}10) =$ ______________________	BA_p in ft^2/acre $= n(BAF)$
$RG10 = RG5 + RG5P =$ ______________________	$CSI_p = \Sigma CSI_i$/No. of tree
$D_B = d.b.h. - 2(RG10) =$ ______________________	$QMSD_p$ in inches =
$CSI_i = \pi\left(\frac{d.b.h.^2}{2}\right) - \pi\left(\frac{D_B^2}{2}\right) =$ ______________________	$\sqrt{183.3465\ (BA)} =$ ___
$TPA_i = BAF/0.005454\ D_i^2 =$ ______________________	$CCF_p = 50.58 +$
	$5.25\ (BA_p/QMSD_p) =$ _
$TH = \frac{d}{100}(TR - BR) =$ ______________________	SI_p (See Appendix tables
	$A_p = \Sigma A_i/2 =$ ______

APPENDIX A—DATA FORM AND COMPUTATIONAL FORMULAS FOR VARIABLES REQUIRED TO DETERMINE POTENTIAL THINNING RESPONSE OF STANDS

PERSON COLLECTING DATA: ____________ STAND I.D. ____________

DATE: ____________ STAND BAF (Ft^2/acre) ____________ SAMPLE POINT ______ of ______

	Past Radial Growth (PRG)						Clinometer Data							
		Years 1-5		Years 6-10										
	d.b.h.$_i$	Core 1	Core 2	Core 1	Core 2	Stump Age (A_i)	Distance (d)	% to top (TR)	% to base (BR)	Total Height (TH)	CCF_p	D_B	CSI	SI_p
	in	0.01 in	0.01 in	0.01 in	0.01 in	yrs	ft			ft		in	in^2	ft
Dominant Tree														
Codominant Tree							N/A	N/A	N/A	N/A				N/A

VARIABLE PLOT CRUISE (Enter D_i of "Count" Trees, i = 1 to n)

Tree No.:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	n
D_i (0.1 inches):																
Trees/acre (TPA):																

COMPUTATIONAL FORMULAS AND VALUES

Individual Trees

$\pi = 3.1416$

RG5 = PRG(1-5) = ____________

RG5P = PRG(6-10) = ____________

RG10 = RG5 + RG5P = ____________

D_B = d.b.h. − 2(RG10) = ____________

$CSI_i = \pi\left(\frac{\text{d.b.h.}^2}{2}\right) - \pi\left(\frac{D_B^2}{2}\right) =$ ____________

$TPA_i = BAF/0.005454\ D_i^2 =$ ____________

$TH = \frac{d}{100}(TR - BR) =$ ____________

Sample Points

$TPA_p = \Sigma TPA_i =$ ____________

$D_p = \Sigma \text{d.b.h.}_i/2 =$ ____________

BA_p in ft^2/acre = n(BAF) = ____________

$CSI_p = \Sigma CSI_i$/No. of trees = ____________

$QMSD_p$ in inches =

$\sqrt{183.3465\ (BA)} =$ ____________

$CCF_p = 50.58 +$

$5.25\ (BA_p/QMSD_p) =$ ____________

SI_p (See Appendix tables 4-8) = ____________

$A_p = \Sigma A_i/2 =$ ____________

Stand

$D = \Sigma D_p$/No. of sample points = ____________

$A = \Sigma A_p$/No. of sample points = ____________

$TPA = \Sigma TPA_p$/No. of sample points = ____________

$BA = \Sigma BA_p$/No. of sample points = ____________

$CSI10B = \Sigma CSI_p$/No. of sample points = ____________

$QMSD = \Sigma QMSD_p$/No. of sample points = ____________

$SI_{100} = \Sigma SI_p$/No. of sample points = ____________

Stand Means (from above formulas)

BA = ____________

QMSD = ____________

D = ____________

A = ____________

CSI10B = ____________

SI_{100} = ____________

APPENDIX B: SITE INDEX TABLES

Table 4—Heights of dominant trees at CCF levels of 125 or less for site index classes 30 to 100 by decadal ages 30 to 200 years (Alexander and others 1967)

	Site index class							
Total age	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Years	*Height in feet*							
30	16	20	24	28	32	36	40	45
40	18	23	28	34	39	44	49	55
50	20	26	32	39	45	51	58	64
60	22	29	36	44	51	58	65	72
70	24	32	40	48	56	64	72	80
80	26	35	44	52	61	70	79	88
90	28	37	47	56	66	75	85	94
100	30	40	50	60	70	80	90	100
110	32	42	52	63	73	84	94	104
120	34	44	55	66	76	87	98	108
130	35	46	57	68	79	90	101	111
140	37	48	59	70	81	92	103	114
150	39	50	61	72	83	94	105	116
160	40	51	62	73	84	96	107	118
170	42	53	64	75	86	97	108	119
180	43	54	65	76	87	99	110	120
190	45	56	67	78	89	100	111	122
200	46	57	68	79	90	101	112	123

Table 5—Heights of dominant trees at CCF 200 for site index classes 30 to 100 by decadal ages 30 to 200 years (Alexander and others 1967)

	Site index class							
Total age	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Years	*Height in feet*							
30	14	18	21	25	28	32	35	38
40	16	21	25	30	35	39	44	48
50	18	24	29	35	41	46	52	58
60	20	27	33	40	47	53	60	66
70	22	30	37	45	52	59	67	74
80	24	32	41	49	57	65	73	81
90	26	35	44	53	62	70	79	88
100	28	37	47	56	66	75	84	94
110	30	40	49	59	69	79	88	98
120	32	42	52	62	72	82	92	102
130	33	44	54	64	74	85	95	105
140	35	45	56	66	77	87	98	108
150	37	47	58	68	79	89	99	110
160	38	49	59	70	80	91	101	112
170	40	50	61	71	82	92	103	113
180	41	52	62	73	83	94	104	114
190	43	53	64	74	84	95	105	116
200	44	54	65	75	86	96	106	117

APPENDIX B: (Con.)

Table 6—Heights of dominant trees at CCF 300 for site index classes 30 to 100 by decadal ages 30 to 200 years (Alexander and others 1967)

	Site index class							
Total age	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Years	*Height in feet*							
30	12	14	17	20	22	25	28	30
40	14	17	21	25	29	33	36	40
50	16	21	25	30	35	40	45	50
60	18	24	29	35	41	47	52	58
70	20	26	33	40	46	53	59	66
80	22	29	36	44	51	59	66	73
90	24	32	40	48	55	64	72	80
100	26	34	43	51	60	69	77	86
110	27	36	45	54	63	72	81	90
120	29	38	48	57	66	75	85	94
130	31	40	50	59	69	78	88	97
140	33	42	52	61	71	81	90	100
150	34	44	54	63	73	83	92	102
160	36	46	56	65	75	84	94	103
170	38	47	57	66	76	86	95	105
180	39	49	58	68	77	87	97	106
190	40	50	59	69	79	88	98	108
200	41	51	61	70	80	90	99	109

Table 7—Heights of dominant trees at CCF 400 for site index classes 30 to 100 by decadal ages 30 to 200 years (Alexander and others 1967)

	Site index class							
Total age	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Years	*Height in feet*							
30	9	11	13	15	17	18	20	22
40	11	14	17	20	23	26	29	32
50	13	17	21	25	29	33	37	41
60	15	20	25	30	35	40	45	50
70	17	23	29	35	40	46	52	58
80	19	26	32	39	45	52	59	65
90	21	28	36	43	50	57	64	72
100	23	31	39	46	54	62	70	77
110	25	33	41	49	57	66	74	82
120	27	35	44	52	60	69	77	86
130	28	37	46	54	63	72	80	89
140	30	39	48	56	65	74	83	92
150	32	41	49	58	67	76	85	94
160	34	42	51	60	69	78	86	95
170	35	44	53	61	70	79	88	97
180	36	45	54	63	72	81	89	98
190	38	47	55	64	73	82	91	99
200	39	48	57	65	74	83	92	101

APPENDIX B: (Con.)

Table 8—Heights of dominant trees at CCF 500 for site index classes 30 to 100 by decadal ages 30 to 200 years (Alexander and others 1967)

	Site index class							
Total age	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
Years				*Height in feet*				
30	7	8	9	10	11	12	13	14
40	9	11	13	15	17	20	22	24
50	11	14	17	20	24	27	30	33
60	13	17	21	25	29	33	38	42
70	15	20	25	30	35	40	45	50
80	17	23	28	34	40	45	51	57
90	19	25	32	38	44	51	57	63
100	21	28	35	42	48	55	62	69
110	23	30	37	44	52	59	66	74
120	24	32	40	47	55	62	70	78
130	26	34	42	49	57	65	73	81
140	28	36	44	52	59	67	75	83
150	29	37	45	53	61	69	77	85
160	31	39	47	55	63	71	79	87
170	33	41	49	57	65	73	81	89
180	34	42	50	58	66	74	82	90
190	35	43	51	59	67	75	83	91
200	36	44	52	60	68	76	84	92

Cole, Dennis M. 1987. Ranking thinning potential of lodgepole pine stands. Gen. Tech. Rep. INT-229. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 14 p.

This paper presents models for predicting edge-response of dominant and codominant trees to clearing. Procedures are given for converting predictions to a thinning response index, for ranking stands for thinning priority. Data requirements, sampling suggestions, examples of application, and suggestions for management use are included to facilitate use as a field guide.

KEYWORDS: *Pinus contorta*, silviculture, thinning priorities